Possible Long-Term Improvements to the Advanced Photon Source

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(Talk previously given at the 2003 PAC in Portland, OR)

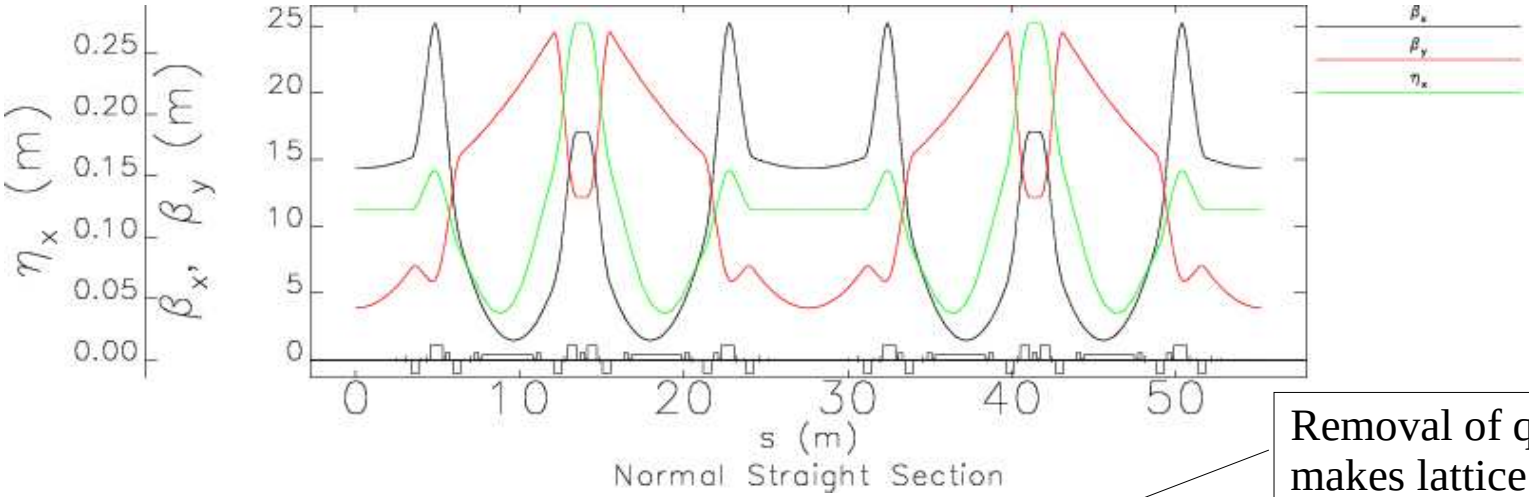
Brightness Improvement Possibilities

- Longer straight sections
- Increase damping
  - RF frequency shift
  - Add gradient to dipole
- Energy Recovery Linac using APS ring
- Whole new ring
  - 80 sectors instead of 40 sectors
  - Extreme Photon Source (XPS)

Longer Straight Section

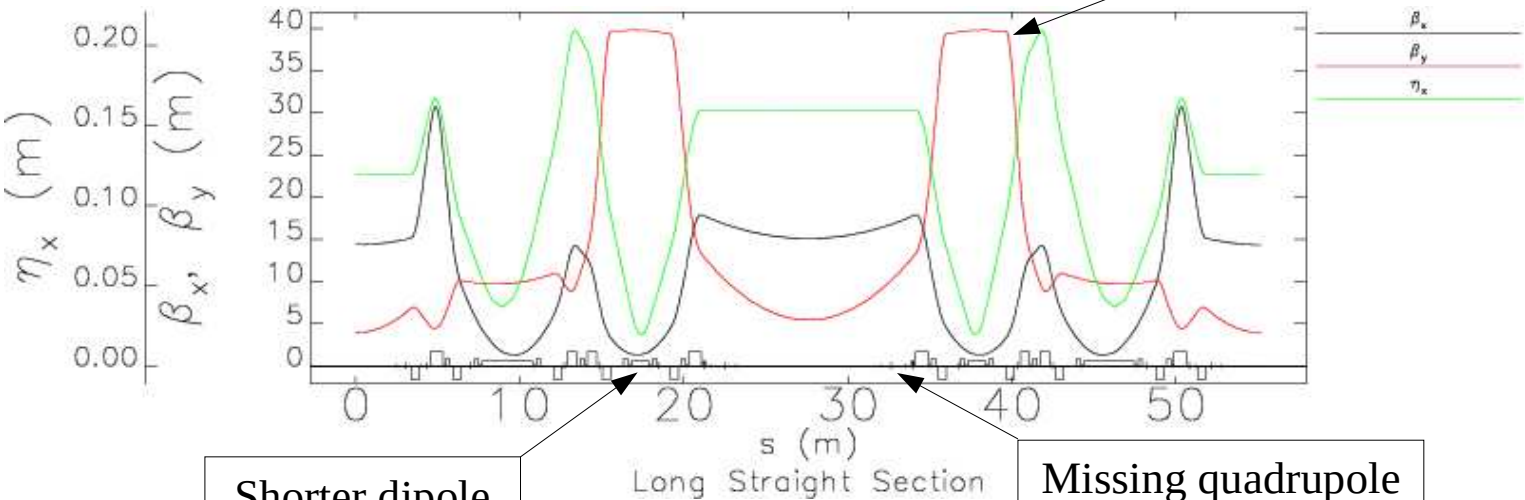
- Makes source brighter and more versatile.
- Presently 5 m available for 2 IDs of 2.4 m.
- 3 IDs or 4 IDs (?) per straight section.
- 9 m may be possible by:
  - Removing one magnet from triplet
  - Shortening dipole from 3m to 1m (0.6 T ➔1.8 T)
    - Forces many other redesign, including magnet layout.
- Identification of design issues under way.

Long Straight Section



Normal Straight Section

Removal of quadrupole makes lattice less flexible



Long Straight Section

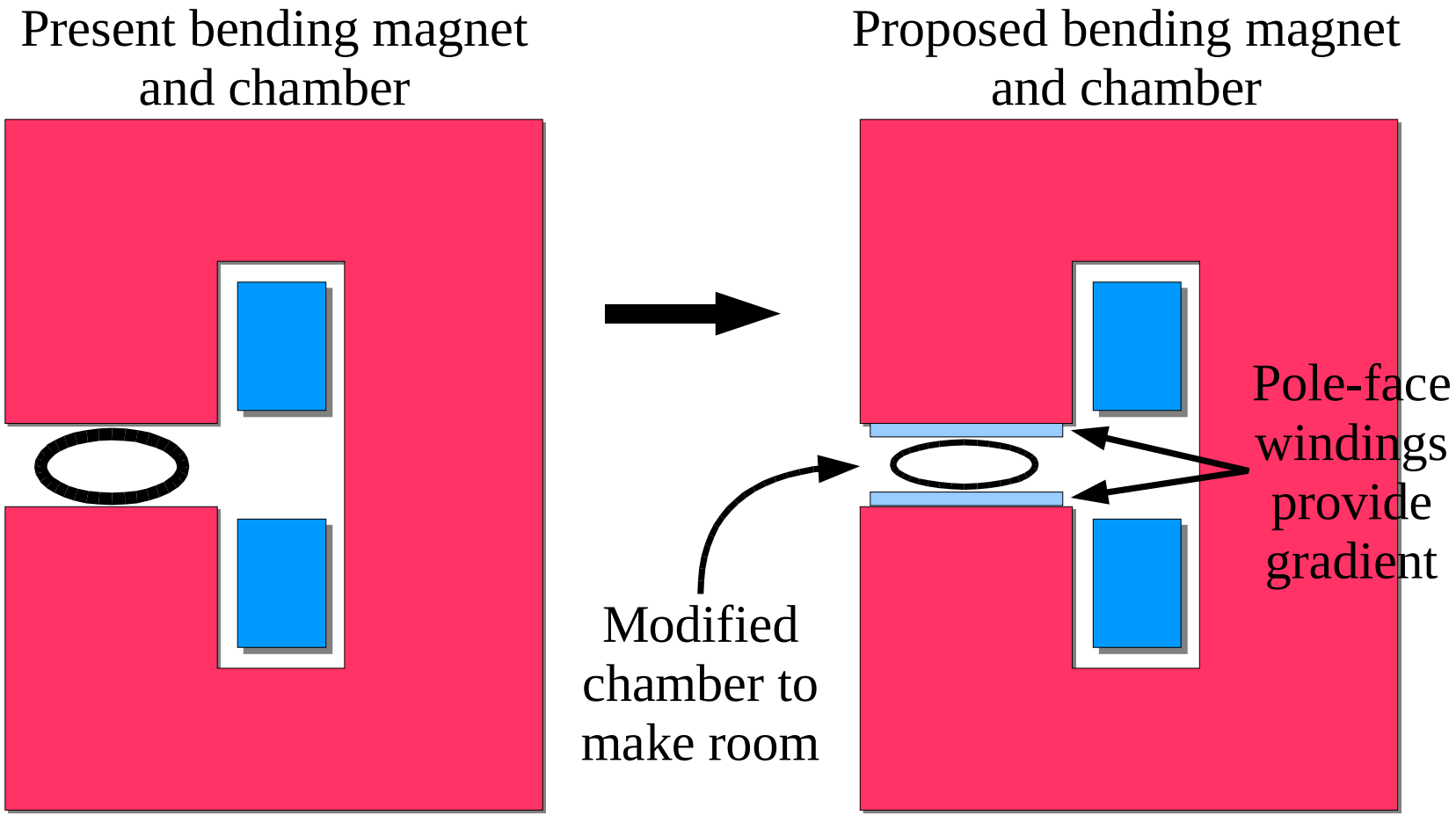
Shorter dipole

Missing quadrupole

RF Frequency Shift

- Did modeling and machine studies.
- ε_{eff} : 3.0 nm-rad ➡2.5 nm-rad with δ= -1.0 %
- Orbit at ID source shifts by -2 mm in x.
  - Steering back restores the original emittance. 
  - Perhaps angle steering is sufficient?
- Changing rf frequency invites operational difficulties.

Possibility for 1.8 nm-rad Emittance

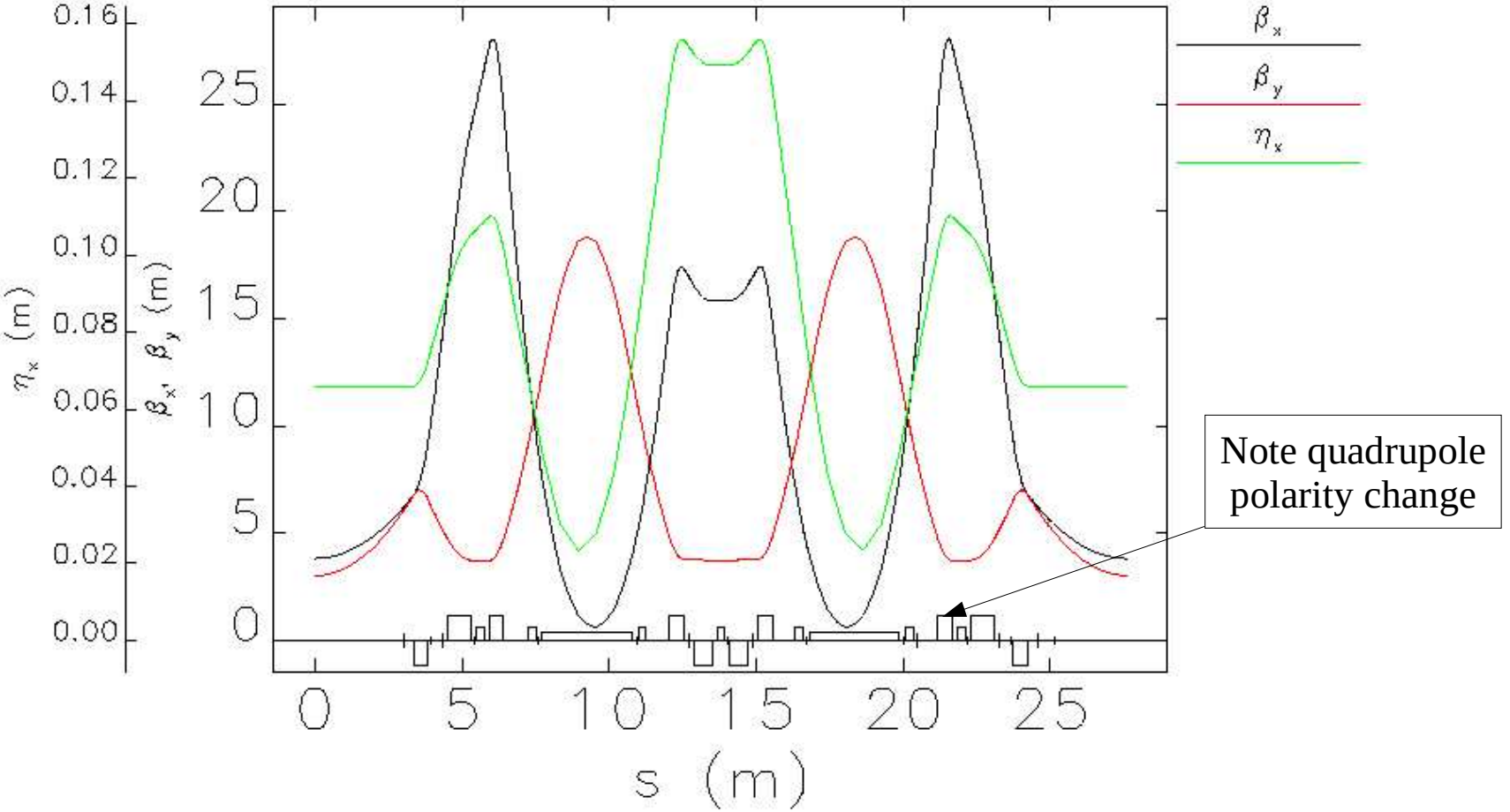


- Can be done a few sectors at a time
- Cooling the windings will be a challenge

Dipole with Gradient

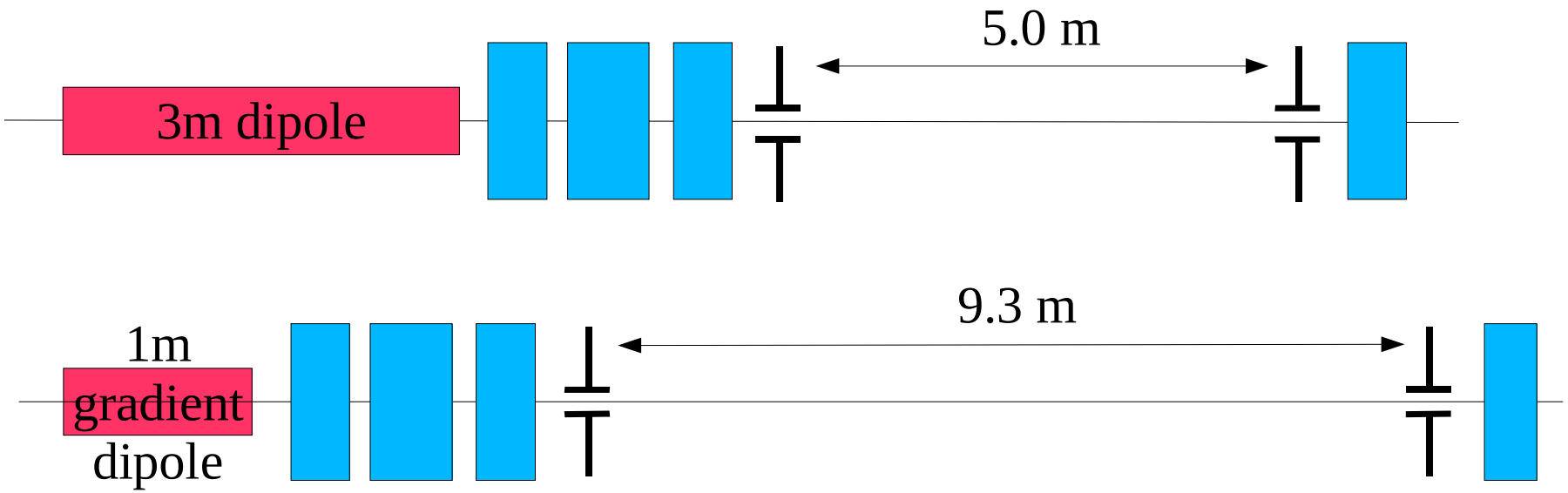
- Optimized gradient reduces ε_{eff} from 3.0 nm-rad to 1.8 nm-rad.
- $(\nu_x , \nu_y) = (36.2, 19.27) \rightarrow (46.2, 32.27)$.
- Normalized gradient k = -0.17 m^{-2}, B = 0.2 to 1T.
- 10 kA-turn pole face windings.
  - Assuming 10 A/mm^2, need 10 mm coil thickness.

Dipole with Gradient



Longer Straight Section and Gradient

- Combine previous concepts.
- ε_{eff} of 1.7 nm-rad.
- Chromaticity correction difficult.

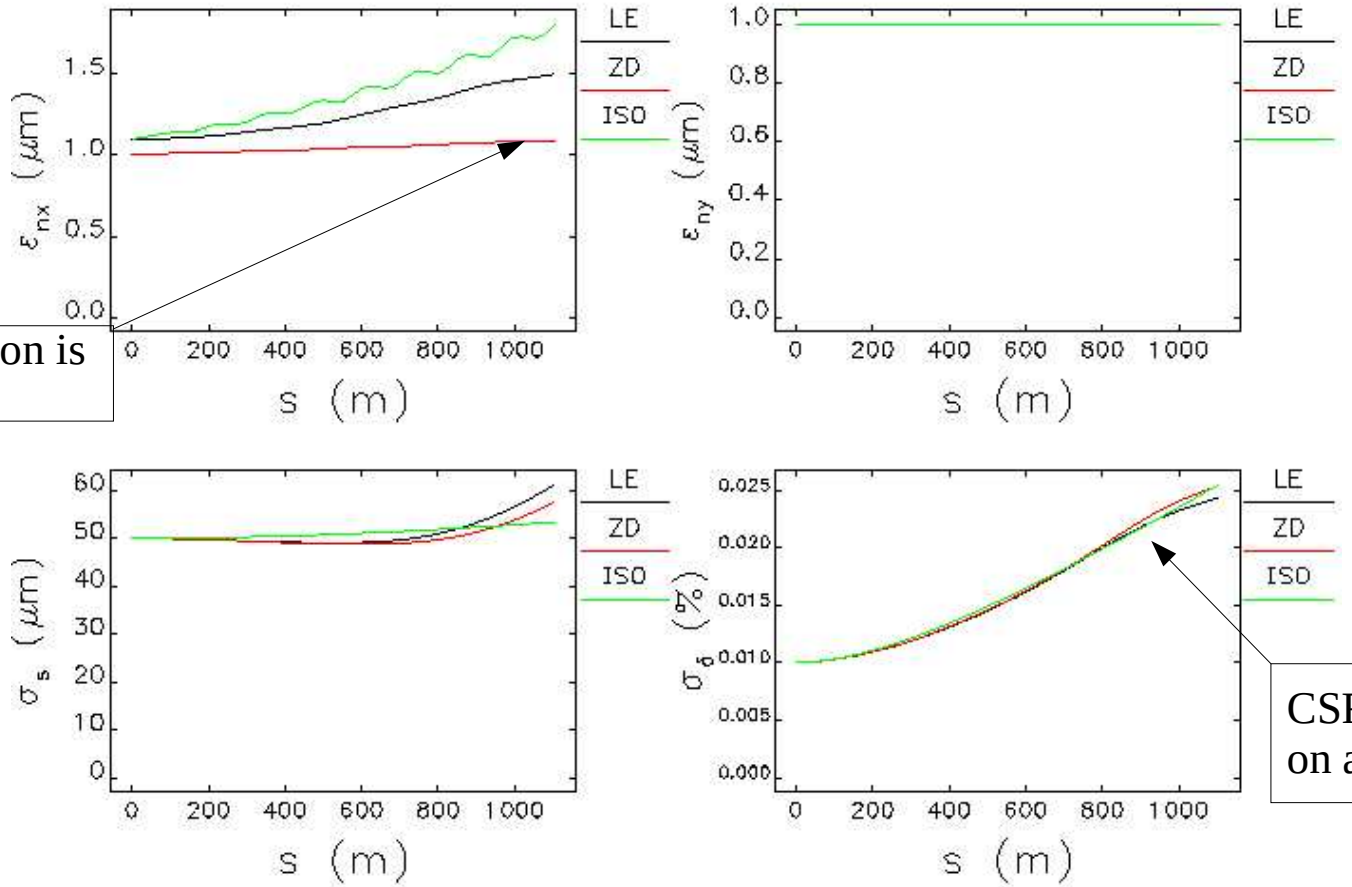


Energy Recovery Linac with APS

- ERL proposals feature arcs that look like half a storage ring.
- We can imagine upgrading APS to an ERL, with circulation of ERL beam for one or many turns then returned to the linac.
- The ERL could be built and partially commissioned without disrupting APS operations.
- Preliminary evaluation of incoherent (ISR) and coherent synchrotron radiation (CSR):
  - Investigated three lattices: zero-dispersion (ZD), low-emittance (LE), isochronous (ISO).

One-turn Growth of Beam Parameters

Initial values: 50 pC/bunch, σ_δ=0.01%, ε_n=1 μm-rad, σ_z=50 μm



Zero dispersion is clear winner

CSR has same effect on all lattices

Energy Recovery Linac with APS

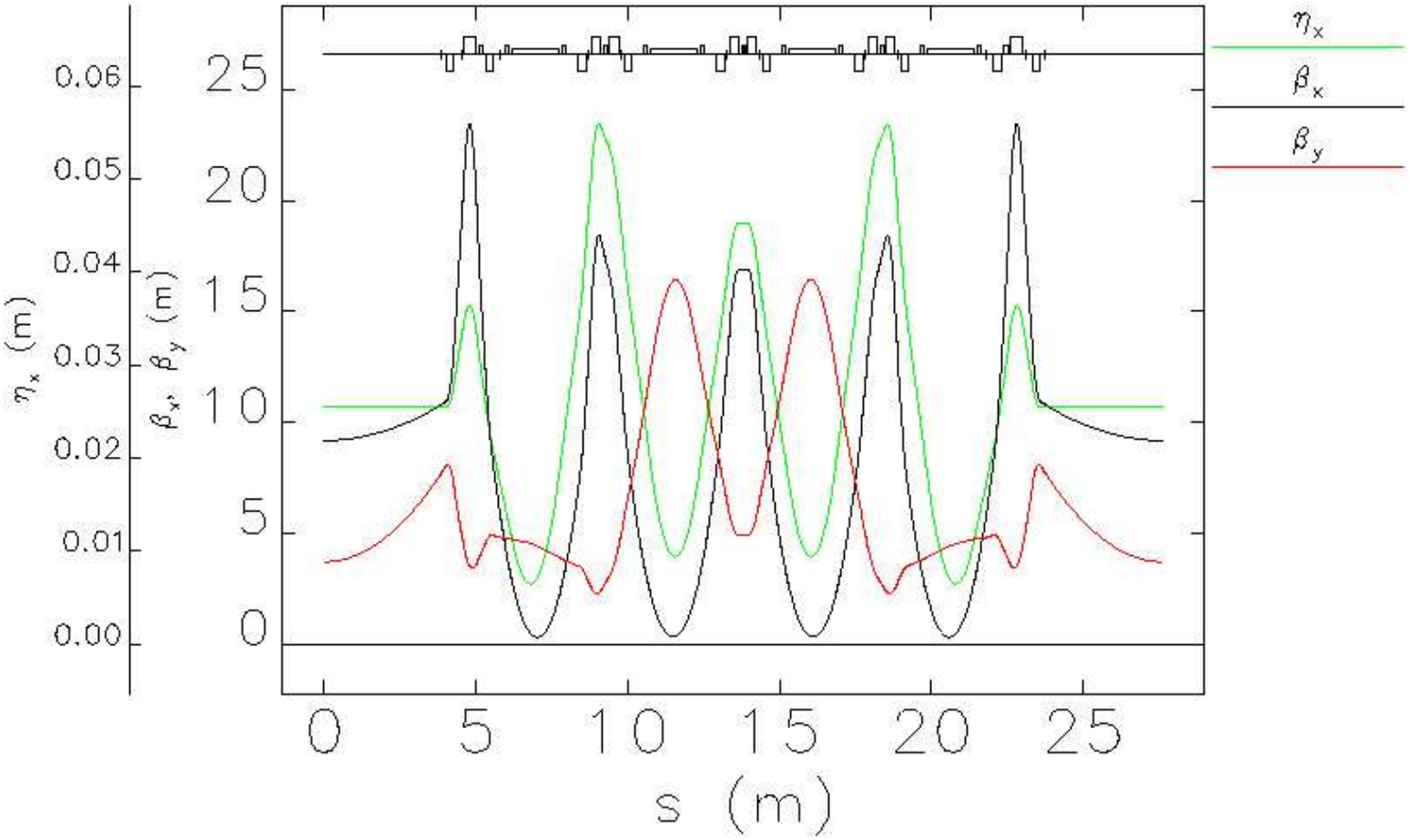
- Relaxing σ_z requirements allows higher charge.
- Beam with σ_z=300 μm (6x longer) and more charge (100 pC) have much less growth, and allows the possibility of multiple turns.
- Need to do start-to-end simulation plus add wake fields to SR.

More Extensive Upgrades

- Take a lesson from SPEAR:
  - Replace the storage ring.
  - Keep the beamlines.
- Eighty-sector ring:
  - Halve all magnets of present APS, double the cells.
  - Remove half of straight sections leaving 40 long straight sections.
- eXtreme Photon Source (XPS)
  - 3 strong gradient dipoles per sector.

Eighty-Sector Ring

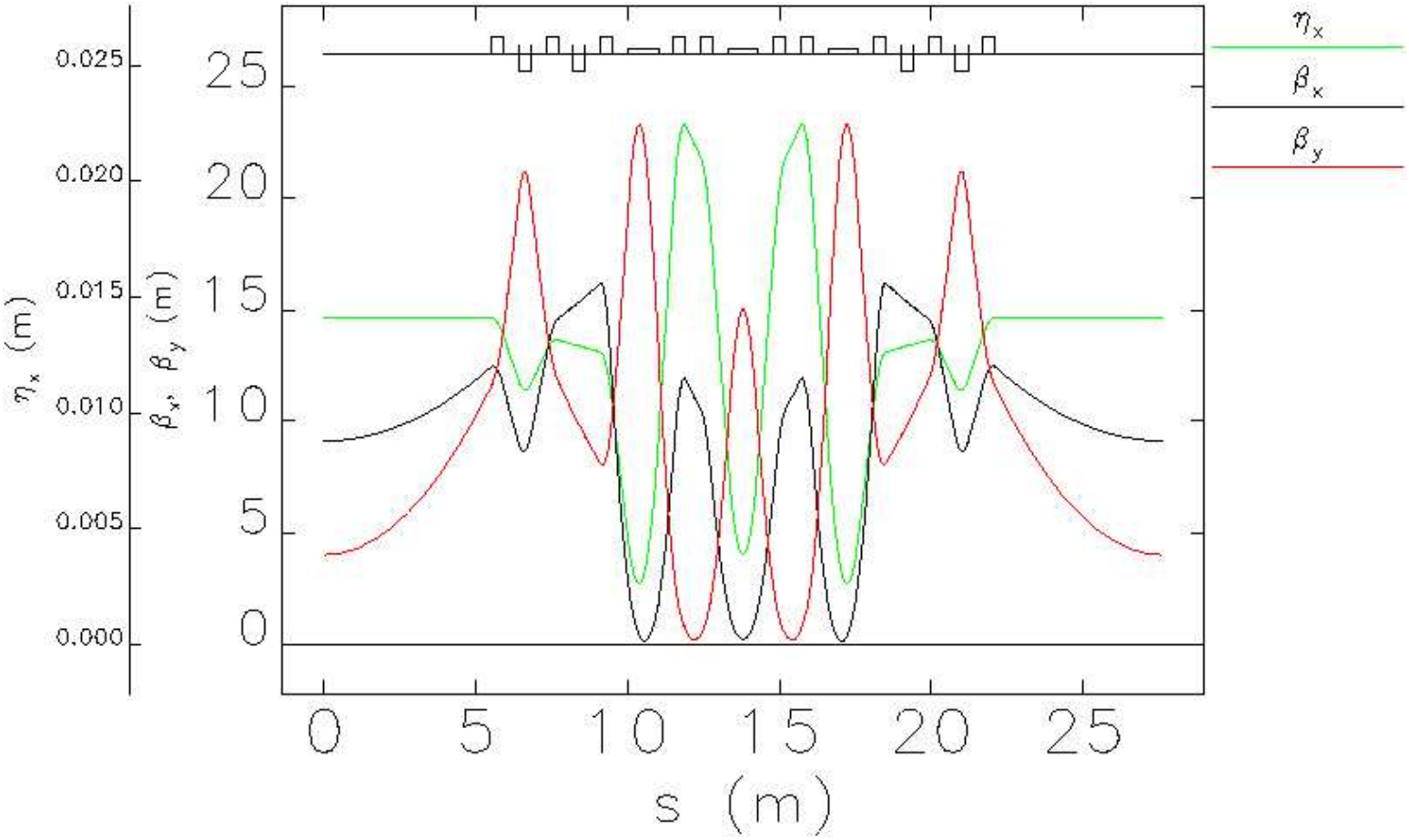
- 10 times smaller emittance (0.3 nm-rad).
- 7.6 m straight section



A True Next-Generation Upgrade

- Our "XPS" design is ~4000 times brighter than APS
  - Emittance is 0.075 nm-rad (same as an ERL).
  - 10m-long IDs and flexible beta functions.
- The magnet technology is very challenging
  - 12-pole variable permanent magnets instead of quadrupoles and sextupoles.
  - Dipoles with strong gradient and sextupole terms.
- XPS is at the borderline between the possible and impossible.

Extreme Photon Source



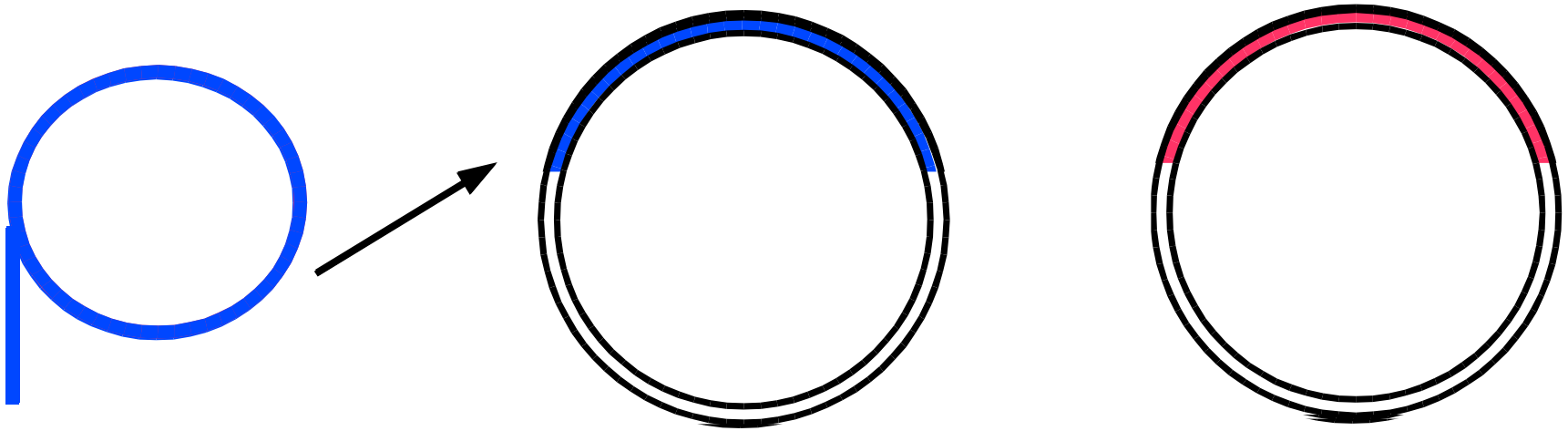
XPS Accelerator Complex

- Due to ultra-low emittance, XPS will have
  - Very short lifetime (45 minutes for 1 mA/bunch)
  - Very small dynamic aperture (0.75 mm)
- We envision a "replace and reuse" cycle

Existing linac and 7 GeV booster

Accumulator & damping ring (existing APS)

XPS ring



Conclusion

- Progression to higher brightness using increasingly speculative concepts, some of which require new technologies.
- What has been investigated so far on these promising concepts makes continued investigations worthwhile.